Analyzing the West Nile Virus 2014 outbreak in Orange County

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Abstract

Mosquito-borne diseases are major threats to public health across the world. Therefore, it is crucial to analyze mosquito-borne disease outbreaks to determine which factors increase mosquito breedings and diseases. We investigated the correlation between droughts and waste management with the 2014 West Nile Virus outbreak in Orange County. We hypothesized that waste management contributed to the 2014 Orange County West Nile Virus outbreak. We gathered precipitation, land cover, and waste management data from the time frame 2011-2018. We collected data from GLOBE Observer, Giovanni NASA earth science data, NOAA National Centers for Environmental Information, Collect Earth Online, and Orange County Mosquito and vector control district. We found that 2014 showed an increase in Orange County's waste production as well as statistical significance between the average perception of 2013 compared to 2011. We concluded that though the drought was the major cause of the 2014 WNV in Orange County as proven by experts, the increase in waste production may have also contributed to the rise of WNV human cases. This stresses the importance of the need for an increase in waste management in Orange County as it provides a sanitized environment, decreases WNV human cases, and improves the economy through methods such as recycling.

Keywords: mosquitoes, Orange County, rainfall, West Nile Virus, waste management

Research Questions:

1. Does waste management control affect the spread of mosquito-borne disease? Is important because it also helps to link mosquito disease spread to more environmental factors.
2. Is there a link between the spread of mosquito-borne disease and environmental factors? Is important as it helps to narrow research down.
3. Is there a link between mosquito-borne disease and climate factors? Is important as it also helps to narrow the research and file the selected data into its category.

Introduction

Mosquitoes are one of the deadliest creatures in the world, transferring viruses, parasites, and bacteria. Each year, about 700 million people contract mosquito-borne illnesses and more than 1 million people die from these diseases (American Mosquito Control Association, 2022). Mosquitoes can spread diseases such as West Nile Virus (WNV), malaria, dengue, yellow fever, zika, and chikungunya. These diseases are deadly and especially life-threatening for immunocompromised individuals and children as they do not have a developed immune system (The Children's Hospital of Philadelphia, 2019). Currently, there are no medicines or vaccines for such diseases. Mosquitoes tend to thrive in environments with water with little to no flow, and areas with moist soil and precipitation (Centers for Disease Control and Prevention, 2022). It is essential to analyze the causes of mosquito-borne disease outbreaks to prevent future epidemics. The objective of this project is to analyze the 2014 WNV outbreak in Orange County.

The mosquito outbreak in 2014 in Orange County resulted in 90 human infections, approximately seven times the diagnoses in 2013 (Gorman et al., 2014). Experts in the field

believe that the drought of 2014 played a major role in the spread of mosquito disease at that time. Drought causes an increase in the spread of WNV as mosquitoes such as *Cx. pipiens* to benefit from urban basins with a concentration of organic matter (Weicheld et al., 1970). Additionally, droughts can decrease mosquito predators such as dragonflies and frogs. As a result, mosquitoes breeding in wetlands increases. Moreover, drought can bring avian reservoirs closer to mosquitoes causing an increase in virus circulation (Wang et al., 2010).

Waste production provides adequate breeding sites for mosquitoes as water may collect in bottles, tires, and cans. A study by Desiree LaBeaud et al. found that mosquito breeding increases where there are vast amounts of waste production such as in Kenya (Stanford University, 2022). Mosquitoes may breed in soda bottles, plastic food jars, and laundry detergent jugs. With the previous knowledge that there is a correlation between an increase in waste production and mosquito breeding, we hypothesized that waste management contributed to the 2014 Orange County West Nile Virus outbreak.

Orange County, California is home to a variety of environments and places to live, with a mix of high and low socioeconomic styles of living (Orange County Government, 2022). Additionally, California has a variety of weather patterns ranging from droughts to high levels of rainfall. Orange County was chosen as the area of interest to study the region on a granular level. The data was collected from the time frame of 2011-2018 which included waste management and precipitation. We found a correlation between relatively low average precipitation and an increase in waste production with the 2014 WNV outbreak in Orange County.

Methods

Data Collection

To analyze climate and environmental factors causing the spread of mosquito-borne disease, we analyzed the historical data of precipitation, waste management, WNV cases as well as GLOBE land cover data. The study site we chose was Orange County, California. We utilized the websites GLOBE Observer, The National Weather Service, NASA's Giovanni data software, Collect Earth Online, and Orange County Mosquito and Vector Control District. To get our land cover and mosquito habitat data, we used GLOBE Observer's data mapping to look for data collection sites from the area and dissected the data to add to our background for the area **(Figure 1a-b)** (Globe Observer, 2022). Additionally, we utilized Collect Earth Online to analyze land cover data of an Area of Interest in Orange County **(Figure 2)** (Collect Earth Online, 2022). We then used Orange County mosquito and vector controls data to get the mosquito disease data for recent years in Orange County **(Figure 3)**. Once we had the mosquito data, we used the National Weather Service and NASA's Giovanni software to get precipitation data for Orange County during the years 2011-2018 **(figure 4)** (Giovanni, 2022). We then used Google Maps to locate and identify recycling centers in the Orange County area, and once we had the data for those three variables we graphed them and looked for common trends throughout the years from Orange County's open access data **(Figure 5a-b).**

In order to mathematically check our data, we used Giovanni's graphing program to graph our data in correspondence throughout the year so we could overlay the graphs to see sudden decreases or rises. We also utilized a t-test for statistical analysis in order to show Orange County's drought in 2014.

Statistical Analysis

The significant threshold utilized was $p < 0.05$. The equation used for the t-test is given below:

$$t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\left(\frac{(N_1-1)s_2^2}{N_1+N_2-2}\right)\left(\frac{1}{N_1}+\frac{1}{N_2}\right)}}$$

Where n is the sample size, X is the sample mean, s^2 is the variance, $Subscript_1$ is sample 1, and $Subscript_2$ is sample 2.

Results

The data of West Nile Virus cases per 100,000 people indicates the outbreak of 2014 which then correlates with the other graphs provided **(Figure 3)**. The mean of the WNV cases data is 4.225 because of the outbreak in 2014 that swayed the data that ranged from 2011 to 2018. The outbreak had almost 9 cases per 100,000 people in Orange County that was almost three times as much as the next highest outbreak of cases during the eight-year time range. The WNV cases, the precipitation, and the waste management graphs comparing the state of California to Orange County were consistent during the year of 2014.

A t-test for two independent means of rainfall in Orange County was conducted on the values of 2014 compared with the values of each year from 2011-2013 and 2015-2018. The null hypothesis states that the mean of the two populations is equal. For 2014 and 2011 the *p*-value resulted in .34704 ($p > .05$). For 2014 and 2012 the p-value resulted in .413179 ($p > .05$). For 2014 and 2013 the p-value resulted in .186444 ($p > .05$). For 2014 and 2015 the *p*-value resulted in .287539 ($p > .05$). For 2014 and 2016 the *p*-value resulted in .287539 ($p > .05$). For 2014 and

2017 the *p*-value resulted in .280631 ($p > .05$). For 2014 and 2018 the p-value resulted in 0.24438 ($p > .05$). However, the p-value for 2011 compared to 2013 resulted in .034028 ($p < .05$).

We saw consistent trends of outbreaks from 2011 until 2014 where there was a drastic increase in the number of cases and then back to the stable trends afterward. We found correlating factors between the outbreak of the WNV and precipitation as well as waste management. In 2014 there was an increase in WNV cases (**Figure 3).** This indicates that while WNV cases increased, precipitation levels decreased. As for waste management, the data demonstrates an overall increase of waste in California from 2011-2018 going from 29 to 39 million tons, which can contribute to the attraction mosquitoes carrying WNV has towards Orange County. Our site of Orange County has short, warm, and clear summers with long, cool, and cloudy winters that all lie within the coastal valleys of Santa Ana and the Saddleback. These conditions can be seen in the GLOBE Land Cover data as well. In addition to the other environmental factors, by using the Land Cover data we were able to uncover that about 23.3% of the Land Cover data in Orange County has standing water **(Figure 1a-b)**. The ideal mosquito environment is standing water, both a result of rainfall and poor waste management, therefore mosquitoes are lured in with the standing water coverage. Moreover, utilizing Collect Earth Online, we found that the 3 by 3 km Area of Interest largely consisted of impervious surfaces. This represents a small area of Orange County but may display that the human footprint is large by the large percentage of impervious surfaces **(Figure 2).** This may be related to humans leaving a footprint in terms of waste production.

Discussion

We calculated the statistical difference between the average precipitation of 2014 compared to 2011-2013 and 2015-2018. The *p*-values for each of the years resulted in a $p > .05$, which indicates there was no statistical significance between these years in average precipitation compared to that of 2014. However, there was statistical significance ($p < .05$) in the average precipitation between 2011 and 2013. Dendroecological studies indicate that there may be a lag in terms of weather conditions and disease outbreaks resulting from it (Water Resources Management, 2022). Future studies should collect data through longer time points. A similar study done by Kelly Helm Smith et al. looked at predicting mosquito outbreaks in Nebraska, using temperature and precipitation data (Smith et al., 2022). The difference between these studies is the length of time, location, and variables. The study utilized Nebraska as their select location, used temperature instead of waste management, and used data from 2002-2017. We found that waste management had a relative effect on the spread of mosquito disease, as more trash can cause more mosquito habitats, which in turn has more mosquitoes that can spread the disease. From the drought data compared to the data with mosquitoes at that time, it was predicted that precipitation and waste affected the spread of mosquito-borne disease.

Conclusions

Using a t-test, we found that the average precipitation in 2014 was relatively low, it was not statistically significant from 2011-2013 and 2015-218. Additionally, using Orange County waste management data, we concluded that though the drought was the major cause of the 2014 WNV in Orange County as proven by experts, the increase in waste production may have

contributed to the rise of WNV human cases. This stresses the importance of the need for an increase in waste management in Orange County as it provides a sanitized environment, decreases WNV human cases, and improves the economy through methods such as recycling. Future studies should investigate the correlation between WNV human cases with distinct environmental and social factors. Additionally, future studies should expand the research to the states, countries, and varying parts of the world.

Acknowledgments

The authors would like to acknowledge the support from Dr. Rusanne Low, Ms. Cassie Soeffing, Mr. Peder Nelson, Dr. Erika Podest, Andrew Clark, and peer mentor Paxton Calder. The material contained in this poster is based upon work supported by the National Aeronautics and Space Administration (NASA) cooperative agreements NNX16AE28A to the Institute for Global Environmental Strategies (IGES) for the NASA Earth Science Education Collaborative (NESEC) and NNX16AB89A to the University of Texas Austin for the STEM Enhancement in Earth Science (SEES). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NASA.

Figures

Figure 1a: Area of Interest GLOBE Land Cover Data. Map shows AOI (Area of Interest- List of sample points used to evaluate data in a given location) land cover data.

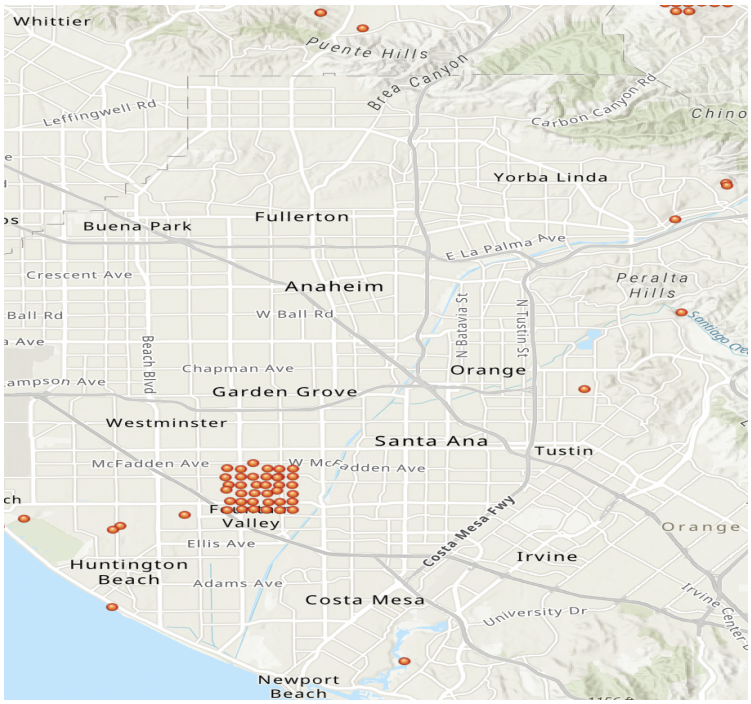


Figure 1b: GLOBE Land Cover Data. Map displayed land cover data with 23.3% of the Land Cover data in Orange County having standing water.

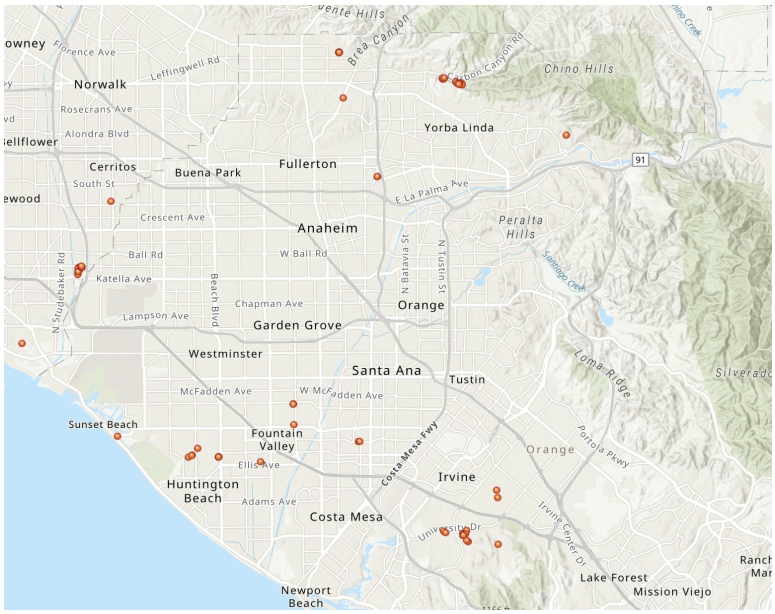


Figure 2: Collect Earth Online Area of Interest Data: Pie chart displaying land cover data of Area of Interest in Orange County.

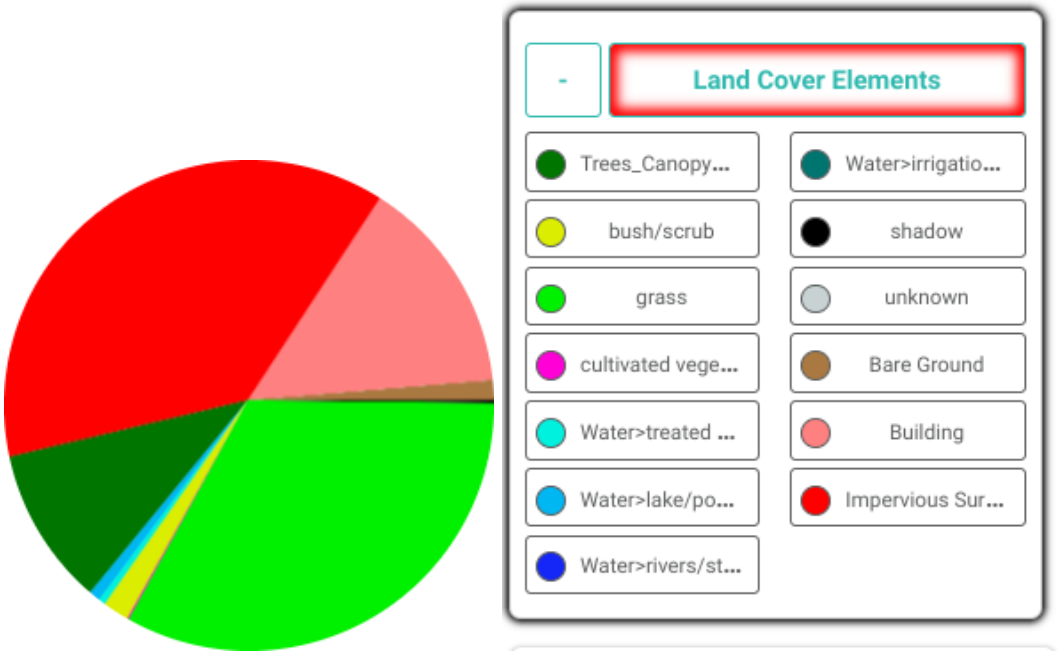


Figure 3: West Nile Virus Rates. Bar graph compares California's West Nile Virus (WNV) rates per 100,000 to Orange County.

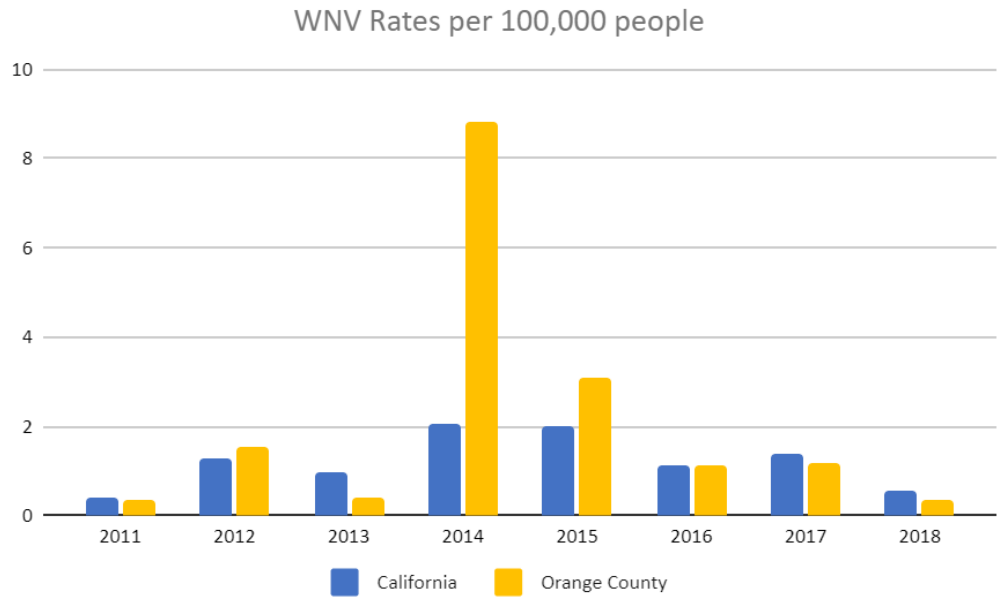


Figure 4: Orange County Precipitation. Bar graph shows Orange County's average precipitation in inches.

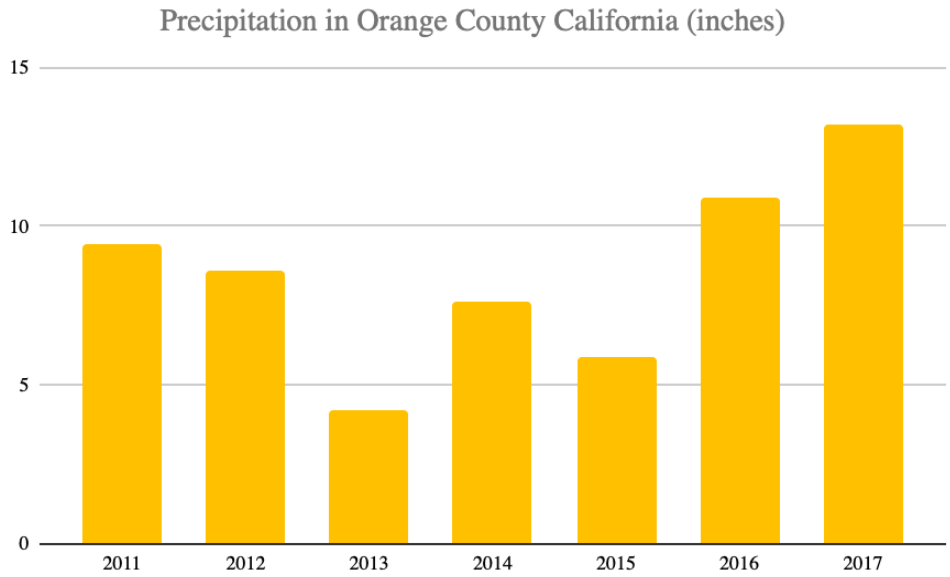


Figure 5a: Orange County Waste Production. Bar Graph compares Orange County's waste production in 2013, 2016, 2017 in California, Irvine, Santa Ana, and Anaheim in pounds per person per day.

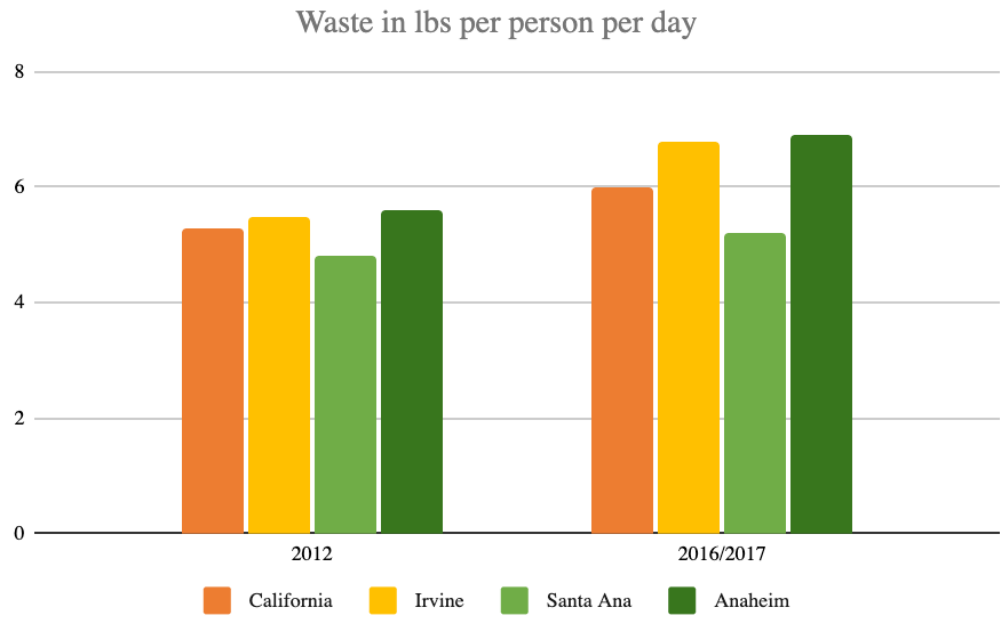
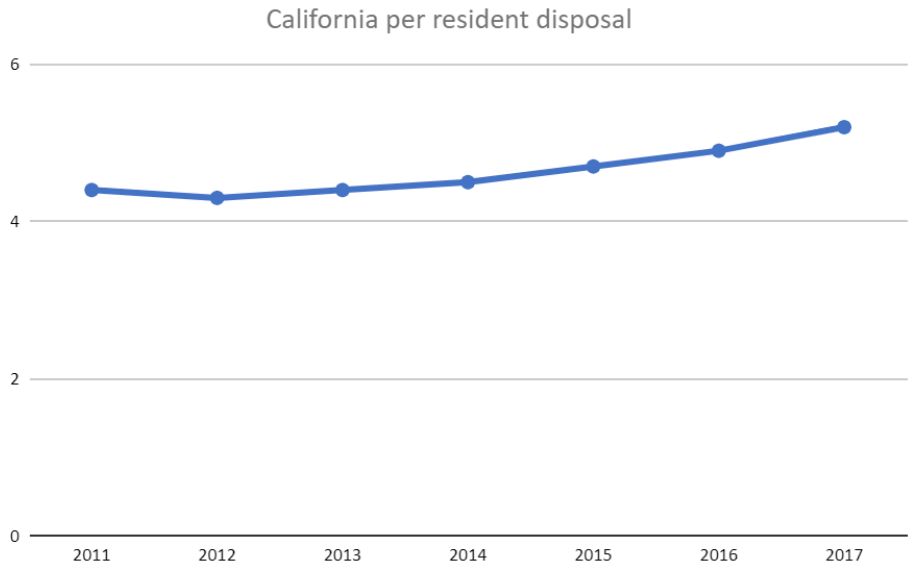


Figure 5b: California Resident disposal. Line graph shows an increase in California's disposal from 2011-2017 per resident.



Badges:

1. **I am a Collaborator:** We are applying for this badge because we formed a collaborative team with differing skills. We worked together with different backgrounds and schools to improve our research. Each member efficiently utilized their skills in order to produce the research. As we worked together we overcame challenges and effectively studied Orange County to analyze its 2014 WNV outbreak.
2. **I make an impact-** Our research studies Orange County's WNV outbreak on a granular level. Such analysis may prevent future outbreaks and epidemics. Additionally, the stress on waste management benefits the environment as well as the economy to decrease poverty levels as well as contribute to the fight against climate change.
3. **I am a STEM Professional-** We worked with STEM professionals such as Dr. Rusty Low, Ms. Cassie Soeffing, and Andrew Clark for inquiries and support in methods and data collections.
4. **I am a data scientist-** We utilized student and professional data in order to find trends that can prevent future mosquito outbreaks. We collected environmental data from GLOBE Observer, Giovanni NASA earth science data, NOAA National Centers for Environmental Information, and Orange County Mosquito and vector control district as well as analyzing our AOI.

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